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ABSTRACT

At the University of Delaware student-teacher communication within the classroom was enhanced through the implementation of a versatile, yet cost efficient, application of computer technology. A single microcomputer at a teacher's station controls a network of student keypad/display stations to provide individual channels of continuous communication from each student to the teacher. The innovation has capabilities far exceeding earlier A-to-E choice-tallying devices. This paper evaluates the technology at the postsecondary level, in the context of an introductory astronomy course. Uses for the technology include the assessment, during lectures, of diverse student attributes such as background, attitudes, misconceptions, specific preparation, and understanding of what has been presented. The most successful use was interactive lectures guiding students through multi-step numerical problems. The technology allows for more individual communication between the teacher and each student, showing the students what the teacher is expecting them to get from the lecture, and showing the teacher if the students are getting it. Appendices include a photograph of the keypads and tables of student evaluation results. (SWC)

Cover Sheet

Computer Assisted Communication within the Classroom:
Interactive Lecturing

Grantee Organization:

University of Delaware
Newark, Delaware 19716

Grant Number:

(FIPSE) P116B91706-91

Project Dates:

Starting Date: August 1, 1989
Ending Date: July 31, 1992
Number of Months: 36

No-Cost Extension Requested: June 4, 1992
Completion (on Grantee's Matching Funds): May 31, 1994

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Grant Award:	Year 1	$ 36,364
	Year 2	$ 23,227
	Year 3	$ 23,477
	Total	$ 83,068

Project Summary

Computer Assisted Communication within the Classroom:
Interactive Lecturing
(FIPSE) PR/AWARD NUMBER P116B91706-91

Student-teacher communication within the classroom is being enhanced by a versatile, yet cost efficient, application of computer technology. A single microcomputer at a teacher's station controls a network of student keypad/display stations to provide individual channels of continuous communication from each student to the teacher. This innovation, with capabilities far exceeding earlier A-to-E choice-tallying devices, is evaluated at the postsecondary level in the context of introductory astronomy courses. Uses include the assessment, during lectures, of diverse student attributes: background, attitudes, misconceptions, specific preparation, understanding of what has just been presented, etc. Most successful are interactive lectures guiding students through multi-step numerical problems.

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Products

Software: Response Acquisition Program
Procedural Manual

Executive Summary

Computer Assisted Communication within the Classroom: Interactive Lecturing

Grantee Organization: University of Delaware, Newark, Delaware 19716

Project Director: Richard B. Herr, (302) 831-2673, herr@brahms.udel.edu

A. Project Overview

In preparing a lecture, the professor programs into a laptop computer a selection of questions to use throughout the class. These include questions on the assigned material, questions to determine background knowledge, survey and evaluation questions, and, particularly, questions leading the class in steps through the lecture topic.

When the teacher selects a question, each student responds through a 21-key (basically numeric) keypad and the response is judged by the criteria written into the computer program by the professor. The numerical responses of the students can be quite general; e.g., -2.746×10^{-14}, as the answer to a quantitative scientific question. The professor's program sends a reply back to the display screen on each student's keypad. These replies are individualized to the judgement criteria, confirming that the student's answer was correct, or identifying a likely error, or giving a hint to try again, or giving the correct solution and answer.

B. Purpose

A variety of purposes are served by the system. It keeps students involved and can lead them through easy steps (assuring that each student has the correct intermediate answers) to the solution of multistep problems, more realistic to science than simple "formula" problems. Primarily, it is an avenue of more individual communication between the teacher and each student. It shows the students what the teacher is expecting them to get from the lecture and it shows the teacher if the students are getting it.

C. Background and Origins

After several years of writing stand-alone computer-assisted-instruction programs, I came to appreciate the enormous difficulty of creating a computer program that allowed for every possible student response, provided appropriate help when needed and never left the student frustrated by misunderstood instructions. If a teacher could be present while the student worked, these problems would be avoided.

About the same time, 1980 to 1981, I was becoming increasingly disheartened by the difficulty of lecturing to the diverse group of students who take Introductory Astronomy. I would lecture without fully appreciating how many were unprepared, what deficiencies some had in their math and science backgrounds and what misconceptions some might be holding.

If only there were a way to get from every student in the class the kind of feedback that is elicited by an instructional computer program. The teacher would know where to put emphasis and be able to talk more effectively to the class. Also, all the student responses could be stored and used to give a more accurate evaluation of student performance than can be obtained from the few, albeit highly stressful, examination days. Students would continually know where they stand, rather than be surprised at the time of an exam by the professor's expectations.

A student response system seemed a possible solution; but, in 1981 these were mostly multiple-choice tallying devices and did not allow the general numerical entry or the important two-way communication. A proposal was written to try to build more general keypads out of hand calculators but this was not funded.

D. Project Description

By 1989, more advanced response-system hardware had become available at an affordable price. The ALS keypads marketed by Reactive Systems were purchased through the FIPSE grant. These have five "function" keys (F1 to F5) as well as 0-9 numeric keys, decimal, minus sign, etc. Their liquid-crystal display screens show the student what s/he has keyed in to send and they allow for 48 characters of alphanumeric reply from the teacher's computer. However, software to take advantage of the keypad capabilities was not provided and had to be written under the FIPSE grant.

More than 200 students have now taken astronomy at the University of Delaware using this system in some developmental form. Continual software improvement allowed more and more of the desired features to be implemented. The F5 function key is set to display an E and to indicate the exponent of 10 for scientific notation; variable credit may be assigned (when desired) to different student answers; output files may be edited and scores imported to any spreadsheet.

In the first semester both students and professor criticized the overhead of wasted class time required for the daisy-chain hookup of the student keypads and the connection of the professor's desktop computer wheeled into the classroom on a cart. Such wasted time has now been reduced to an unobjectionable minimum by installing permanent room wiring with outlets at the student desks and by the professor using a battery powered laptop computer requiring only one easy connection at the lecture table.

E. Project Results

As might be expected for any departure from familiar teaching methods, some student reacted quite positively, some negatively but most accepted it dispassionately. On average, student response was more positive than negative when they rated the system on how helpful it was to their learning astronomy. Test scores for questions that had also been asked to classes prior to use of the response system were disappointingly similar to those of the earlier classes. Also discouraging was the fact that less subject material could be covered than when the class periods were filled with lecture that was virtually uninterrupted by student interactions. This was expected and accepted as the price for covering selected material in greater depth. No control group was possible for this new coverage; but, although students gave their highest endorsement to these interactive-lecture methods for multi-step problems, assessment of the knowledge they acquired made it dubious whether the work required to create such lectures could be justified.

The system will continue to be used and improved. A more thorough statistical evaluation of the enormous body of accumulated data is planned for publication. Because (as described elsewhere) of the delays caused by programming difficulties and the disallowal of a no-cost extension as a result of communication problems within FIPSE, a more complete analysis is not yet possible.

F. Summary and Conclusions

Questioning students to keep them involved in the reasoning steps to a deeper understanding of a topic in not a new pedagogical technique since it dates at least to the time of Socrates. Obviously, it works best when only a few students are involved. The oration or lecture is equally old and a marvelously efficient means of informing a large group of people. This project has shown that today's computer technology can combine elements of both methods.

That combination was found to require an extraordinary amount of work on the part of the teacher to prepare presentations for classes. Questions representing the best instructional use of the system have to be created and completely programmed into an error-free computer file. The most time consuming part of this programming is devising the proper judgement criteria in anticipation of student answers and then phrasing (in three short lines of 16 characters each) appropriate replies to the correct and incorrect answers. In addition, it typically required one to two hours of extra time after each class for follow up work.

We are not considering here the one-time hardware and software development time for the overall project. Nonetheless, it was found that most of the above-considered time surrounding each class was not greatly reduced in the second or third years even though many of the same questions were reused. By the Fall, 1993 semester, just concluded, a more relaxed usage of the keypads was found to be most functional. Deciding not to use a question was much more acceptable to me if I had composed it in a previous year rather than having just spent an hour before class laboring over it.

In balance, the system does contribute to better teaching. Student preparation for class, attentiveness in class and understanding of multistep problems all seem improved but not sufficiently to justify the work required of the teacher. Attendance and classroom discussion are definitely improved, but, again, the bottom line of demonstrably better student performance is disappointing. It will continue to be used and improved in my astronomy classes but with less emphasis than when I felt compelled to make each class an exhaustive trial of the methodology.

G. Appendices

Photograph of keypads and tables of some student evaluations.

Final Report

Computer Assisted Communication within the Classroom: Interactive Lecturing

A. Project Overview

The roots of this project date back to 1981 when I realized that computer technology might provide a solution to some problems that plagued my teaching. My colleagues confirmed these to be common problems, perhaps inherent in a system of mass education. Despite my best efforts, I found that student often came to my classes poorly prepared; their minds tended to wander during class; they missed important points. That meant that they couldn't understand a later concept and their difficulty mushroomed! I would lecture on without really knowing their weaknesses in background, in preparation and in missed concepts.

A test would loom ahead! Panic cramming to retain as much as possible through just one short, but CRITICAL hour. Only then did a clearer picture emerge of how much less I had taught than I thought I had taught. I and my students would be mutually discouraged as we resumed the pattern for the next test.

My dream was of a system by which, at all times during the class, each student would have a private channel of communication with the teacher. By virtue of a FIPSE grant, this dream became the reality of a classroom wired for student response/display pads connected to a central microcomputer operated during class by the teacher.

Although the experiment of how best to use this facility is still in progress, supported by University of Delaware matching funds through May, 1994, sufficient experience has been gained through the Fall, 1993 semester to write a "final" FIPSE report now that that funding has ended.

Approximately 200 student have now (December, 1993) completed courses taught using this system. Of these, 141 took "Introduction to Astronomy I" (PHYS 133) offered in the fall of 1990, 1991, 1992 & 1993. This is the first semester of our most quantitative introductory astronomy course at the University of Delaware and is offered in the usual format of three lecture sessions and one laboratory session each week. In the spring semesters (PHYS 134) of 1991, 1992 & 1993, 59 students used the system. Additionally, 48 students took PHYS 133 and 18 students took PHYS 134 in the academic year 1989-1990 when the system was only partly in place. Since September, 1990, the basic system has not changed dramatically although there have been continual improvements to both the hardware and the software that facilitate its use. This report, therefore, concentrates on the pedagogical results in this later period.

At this time, my conclusion is that the system is of value and will continue to be used and improved but that the bottom line of improved student understanding of astronomy was not sufficient to justify the extraordinary effort required by the teacher to implement the method.

B. Purpose

Science, like mathematics and language, is learned progressively. That is, many concepts cannot be appreciated without first understanding preliminary material. A student who falters on a lower step is unable to climb to the levels expected for postsecondary education. Although this progression is widely appreciated in math and language instruction, and is appropriately addressed in elementary and secondary schooling, this does not seem to me to be the case as often in science. I find students thinking that they can understand, or that they <u>do</u> understand, black holes without first attaining some basic knowledge about the nature of mass, force, gravity, electromagnetic radiation, etc.

This trend may continue in some college astronomy courses where the emphasis is so heavy on description, rather than on science, that the topic seems indistinguishable from mythology: the earth in space is described and understood on no more scientific a basis than some story of our living on the back of a giant turtle in an endless sea.

When quantitative material is introduced in a course, student have been conditioned to expect it to be in the form of "formulas" which they must memorize. The "word problem" is expected to contain a "ham-and-eggs" word association reminding them of the formula to use and should reinforce this by containing the values for all of the quantities on the right-hand side of the formula (and for nothing else). Even the semantics is antithetical to science - the idea that these are application "formulas" rather than relationships among physical quantities in the universe.

My purpose in the interactive-lecture project has been to dispel these misrepresentations of my field and to guide students to a more valid appreciation of what actually constitutes science. After some twenty years of attempting to do this using (mostly) traditional methods of college teaching, I was convinced that I was bucking a system that is comfortably non-demanding for both students and teachers.

The picture presented in the preceding paragraphs is grim - the worst case situation. However, addressing a solution is not made easier by the fact that not all students have had so crippling a preparation for higher education in science. What is the best compromise between attending to the remedial needs of some students without stifling those prepared to gain the most from the course? Unlimited individual attention is an unattainable ideal. Might technology help achieve the desired individual communication while preserving the wonderful efficiency of lecture presentations for mass education?

Many educational buzzwords were apropos to my proposed project: communication, motivation, active learning, nondiscriminatory involvement of the entire class. All of these goals were, in fact, enhanced by the program. The core structure is (1) a question is asked by the teacher, usually via viewgraph, (2) each student enters a response on his/her keypad, (3) the responses are recorded and judged by a previously prepared program in the teachers computer, (4) each student receives back a reply based on the response that s/he entered.

C. Background and Origins

The conceptual origins of the project have been described above. In 1981 I knew of no satisfactory keypads marketed to do what I wanted. That is to allow students to enter any number; e.g., -4.621×10^{-18}, and have it be judged by the instructor's computer. I considered building buffer chips into inexpensive hand calculators so that the displays could be read by a central microcomputer, but that 1981 project was not funded. By 1989 only one vendor (Reactive Systems) had emerged to provide what seemed a viable off-the-shelf unit. They made several models, the most versatile being the Advanced Learning System (ALS). An ALS keypad consists of an LCD screen, with four lines of 16 characters each, and 21 keys including 0-9 numeric keys, a help key and five programmable function keys. The pads are connected by telephone wire and standard modular (RJ11) telephone plugs to a multiplexing unit that interfaces to an IBM-compatible microcomputer through the RS-233 serial port. In comparison to the components contained in a $15 hand calculator, the $210 price per keypad/display unit could only be justified by the limited market. We bought a multiplexer and 64 keypads which arrived in September, 1989.

Unfortunately, the software supplied by the vendor limited the keypads to nothing more than a simple multiple-choice tallying system. The inability to use the function keys, the help key, minus signs, decimal points, and even to enter multidigit numbers made the $210 price tag outrageous. Our programmer who was to customize the vendor's response acquisition program was overwhelmed and had to start from scratch. Reactive Systems seemed unable to fully solve the problem, although by January 1990 they had supplied us with computer routines that we could incorporate to allow sending more general numbers. The help and function keys were still not recognized, even locally within the keypads. A second programmer worked on this problem attempting to write the code to actually reprogram the integrated circuits in the keypads. But it wasn't until September, 1990 (a full year after the pads were purchased) that Reactive Systems was able to supply us with an upgraded EPROM and gave us permission to copy its microcode into our keypads.

During the first semester of trials (Fall, 1989), the students daisy-chained their keypads, plugging one into the next to complete a circuit from the computer interface. This works fine for a small class or for a system that has to be portable; we used it successfully for a November 2, 1991 presentation at a FIPSE Project Directors' Meeting. But, even in a class of only 30, the hookup took an annoying amount of class time and introduced frustrations when someone didn't properly make the connection. Much effort went into creating a permanent wiring scheme for our lecture hall. By the spring of 1990, surface wiring had been installed with telephone style outlets at every other seat providing 100 receptacles for keypads. In March, 1991 we purchased 33 additional keypads and a second interface box. Although it seems unlikely that the ALS system will ever be able to address more than 64 keypads (contrary to the initial expectations from Reactive Systems) the extra pads and interface have proved most desirable as a hardware backup and to allow program development and class preparation on an out-of-classroom system.

Next to the delays created by the insufficiency of the software supplied by the vendor to support their keypads, the most serious obstacle to progress was the loss of our programmer in May, 1991. Attempts to find a satisfactory replacement during the following academic year were unsuccessful. Although a couple of student programmers attempted work on the response acquisition program, no usable additions were produced. One promising programmer did complete an auxiliary utility program to make it easy for teachers to create the question/response files needed for each lecture. Unfortunately he left the university before he could contribute to the response acquisition program.

To assure that the remaining features desired in the program would be completed, a written request for a one-year, no-cost extension of the project was submitted to the FIPSE Program Officer on June 4, 1992. This was confirmed in a FAX received June 12, 1992 requesting budget details which I FAX'ed back on June 17, 1992. Obviously, a more experienced (and more costly) programmer was needed, so approval from FIPSE was obtained, dated December 4, 1992, to merge the remaining money to pay a senior programmer to complete as many of the improvements as the remaining money would allow. Unhappily, the request for no-cost extension was disapproved on the basis of it not having been received prior to July 31, 1992. My March 22, 1993 petition for reconsideration pointed out that, although my extension request had not been transmitted to a Grants Officer until after the deadline, I had submitted it to my Program Officer in a timely manner. Nonetheless, the extension was not approved. An expert programmer was obtained in the fall of 1993 and is being paid with university funds remaining in a matching account.

D. Project Description

CONCEPT: Throughout a lecture class, students are asked questions to which they respond on individual keypads and receive the teacher's preprogrammed replies from a central computer which stores all the data for analysis.

HARDWARE: 21-key, 4x16-character display, numeric keypads from Reactive Systems; IBM-compatible laptop computer; Reactive Systems's interface; and local room wiring.

SOFTWARE: Locally written **Response Acquisition Program (RAP)**, MicroSoft Professional BASIC Compiler; spreadsheet (SuperCalc) for maintaining scores.

PROCEDURE: The teacher brings to the classroom a laptop computer containing RAP (see above), a class-roster-initialization file, and a specific question & response-judgment file for the day's class (the **.DAY** file). This computer is plugged into an interface box which is permanently located in the classroom. As students enter the room they select from a cart of boxes their individually numbered keypads, sit where they like and plug their keypads into outlet boxes behind their seats.

The interactive lecture session begins when the teachers enters "rap" on the laptop computer. RAP accesses the class roster initialization file (INIT.MSG) which attaches student names to pad numbers and which may also contain initial individualized messages to be sent to each student's display screen as in the figure.

```
~1 Eliot      Thomas
Hello Tom,
See me about
math review.

~2 Prufrock   Alfred
Hello Al,
Keep up the
good work!

~3 ...etc.
```

Sample from an INIT.MSG file.

Students receive their personalized messages, which also provide confirmation that they have correctly picked up the keypads that were assigned to them. The messages were written into the INIT.MSG file by the teacher prior to class using any ASCII text editor.

A typical class may start with the professor asking if anyone has questions on the assigned reading for the day. Students respond through the keypad by sending the page number of the material that they don't understand. The students' names and the page numbers appear on the professor's computer screen and the professor responds to the questions. The list of student names and the pages that they questioned are saved in the output file for later reference as to who was participating in class and what readings from the text gave the most trouble.

When there are no more questions from the students, the professor may ask several questions selected as important from the assigned material or from review material. The most practical mechanism for presenting questions was found to be the ubiquitous overhead, "viewgraph," projector. Each student keys in a response which, depending upon the question, may be a numerical answer, a multiple-choice selection, a yes/no or true/false. The responses are judged by the criteria that were entered in the .DAY file by the teacher prior to class. RAP as presently written permits up to eight judgements to distinguish different answers.

Figure 2 shows one question as coded in a .DAY file by the teacher using a text editor or using our aforementioned user-friendly utility for creating .DAY files. This example shows full use of the options to (1) assign credit points, differing for different responses; (2) send appropriate replies back to the students; (3) reflect back the number that the student sent; and (4) permit students to try again, in which case their later answer is the one that counts for the credit.

The beginning of a new question is coded as ~ in column 1 (the leftmost column of a line). Following that line is a full statement of the question terminating when a line is encountered beginning with !. This ! is the code for a judgement line on which must appear a numerical expression; e.g., y=7.2E-6, giving the judgement criterion. In this case, if the student had sent the number 7.2E-6 (or .0000072) he or she would receive back whatever lines (up to 3) are in the .DAY file between that judgment line and the next ! or ~ in a column 1. In the reply to the student, <answer> is the code for sending back to the student the value that the student sent.

Optional characters on the judgement line are [] which enclose a point score that will be given for that answer and * which means that the student may try again using the clue on his/her screen. The example in Fig. 2 uses this device in a lighthearted way to direct all students to the correct answer.

```
~Latitude of Washington?
.
What is our latitude (in degrees)
here in Washington, D.C.?
.
!38<=x<=39 [2]
Congratulations!
U know where U R
Approx 38.9 deg.
!*36.5<=x<38 [1]
Close! You're in
VA; go a bit to
north. Try again
!*39<x<=42.4 [1]
Close! Come
south a bit on
I95. Try again.
!*70<=x<=80 [0]
That looks like
longitude. Try
again for lat.
!*x<=0 [0]
TryAgain. U sent
<answer>
D.C. lat. is >0.
!*x<25.8 [0]
You are south of
Miami. Go north
and try again.
!*x>42.4 [0]
You are north of
Boston. Go south
and try again.
!*25.8<=x<36.5 [0]
You are in deep
Dixie. Travel
north; try again
```

Fig. 2. Sample question in .DAY file.

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While running RAP, the teacher selects the option of asking questions from a .DAY file, then sees a list of the .DAY files in the computer directory, selects the desired .DAY file (usually named with the date; e.g., DEC7.DAY) and is presented with a list of that file's questions. Questions are listed in the order in which they occur in the .DAY file and are identified by the text that appears (see Fig. 2) after the ~ which is the code for the start of a question. When the cursor is placed on a question identifier in the list, the more complete question text (in the lines following the ~ line in the .DAY file) appear in a box on the instructor's screen. If <Enter> is pressed, that question has been selected, polling of the keypads begins and response judgements are those for the selected question.

As students send their responses, their names and responses appear on the instructor's screen. Students do not see this list. When the teacher sees that all, or most, of the students have responded, or that a time limit has been reached he or she ends the polling and is presented with a bar graph showing the number of responses in each of the judgment categories. All of this information is saved in an answer (.ANS) file: the question statement, each student's response and name in the order received, and the bar graph of results. A separate output file contains just the student scores (not all questions are scored) in a matrix suitable for importing to a spreadsheet where analysis can be performed.

Spontaneous questions (not in the .DAY file) may also be asked but student answers for these cannot be judged or scored. In this case a default acknowledgement; e.g., "Your answer <answer> was received," is returned to the student keypads.

Class attendance, of course, is automatically recorded with latecomers, who plugged into the system after the roster initialization, noted in the name list. The lecturer can see this attendance list at any time except when active polling is occurring.

Message files other than INIT.MSG can also be sent to the class during the session. An important use of this is to confidentially send to each pad the student's total present score and grade for the course. Message files for this purpose are easily prepared from the grading spreadsheet (which weights the student's classroom performance with test and lab scores) using macros.

E. Project Results

Within the procedural framework described above, diverse teaching options are possible. In this section I will describe some of the things that I have tried and how well they have worked. The fact that new ways to use the system are continually presenting themselves, leads me to believe that there are many other (very possibly, better) uses of the system than have yet occurred to me. The potential seems great and likely to become even greater as the technology to exchange more complex communications in the classroom becomes more affordable.

Because of the credit points assigned to some of the daily questions, class attendance is higher than in classes where classroom performance is not so routinely evaluated and used as a component of the final course grade. The format of having, essentially, a daily quiz encourages students to keep up and to be prepared for class. This is certainly not a new discovery, but the keypad system facilitates delivery and provides immediate feedback of quiz results to the teacher before beginning a lecture.

Allowing virtually unlimited questioning by students before such quizzes, has engendered more student discussion than I have ever had before in an astronomy class. I have sometimes spent the entire class period responding to good, legitimate questions (as opposed to those introduced to delay quiz questions). Quiz-delaying questions are usually transparent and readily dealt with. Students know that I will completely answer a question even if it is one that I plan to ask them. In fact, I encourage them to try to outguess me, to get on the same wavelength as to what is most important from the reading assignments. It may even be argued that learning to read a science book is a more valuable accomplishment than learning the specific factual material from the course.

A major motivation for this project was to experiment with a more Socratic lecturing style where students are led to an understanding of the subject through a sequence of questions. Prior to lecturing on a topic that requires use of the trigonometric sine, the teacher might ask a non-credit question ascertaining that class members know the mathematical definition and can solve for a numerical answer. Depending on the responses received, the teacher might spend more (or less) time reviewing the prerequisite math. Students missing the question might be directed, through a keypad message, to a math review exercise set up on an out-of-class computer.

Questions to determine ongoing understanding of the lecture may be sprinkled throughout the lecture. The goal is severalfold: to keep the teacher appraised of student progress so that the lecture remains appropriately directed to the audience, to keep the students actively engaged in the learning progression and to give them stimulated opportunities to ask questions. Finally, questions toward the end of the session may carry credit as a test of comprehension and ability to use the concept.

Often a question builds toward a later question to establish first that each student understands the vocabulary or knows a prerequisite piece of factual information. For example, Figure 2 contains a question that might be used to lead toward a question testing whether students realize that the altitude of the north celestial pole (essentially the altitude of the North Star, Polaris) is a measure of the observer's latitude. The Figure-2 question directs every class member to the correct value for the latitude of Washington, D.C. The next question could establish for everyone the definition of "altitude" by asking, "What is the angular distance above the horizon of a star whose altitude is given as 23 degrees? Give your answer in degrees." Then, the focus question, "What is the altitude of Polaris as seen from Washington, D.C.?" The idea may be reinforced by a follow-up question, "Norfolk, VA is 2° of latitude south of Washington. What is the altitude of the north celestial pole at Norfolk?"

Because a live instructor is present when such questions are being asked, oral discussion and clarification is always possible. Thus, although preparation of a bug-free .DAY program is very time consuming, it is not as overwhelming as preparing a self-paced, stand-alone tutorial. Feedback from the students is immediate for each question.

Ideally, students (1) study the assignment before class, knowing that one aspect of the response system will be a quiz on assigned material; (2) use the initial questioning period in class to clarify material that they didn't understand from the reading; (3) follow the lecture using the interactive system to check that they are getting the main ideas and to accumulate daily credit that will make their final grade less dependent on a few tests.

We have called this interactive or participatory lecturing; it combines feedback elements of tutorial CAI with the explanatory discourse of the in-person teacher.

F. Summary and Conclusions

Ongoing evaluation was an inherent part of the project. In the Spring, 1992 semester, midway through the project, oral interviews were conducted, both individually with each student (by the professor) and with the class as a whole (by a professional from our Center for Teaching Effectiveness, with the professor absent). Student evaluations also included a formal, anonymous year-end evaluation (every semester), mid-semester written critiques by the students (most semesters) and evaluations conducted throughout every semester using the classroom keypads to obtain student opinions. A brief "PreTest" was given on the first class day of each course as a measure of student backgrounds (along with the demographic information available from the University Records Office). Every classroom response that every student made on the keypads during the entire course of the semester has been retained in computer retrievable form along with their answers to written test questions. Written tests were prepared to be comparable to those given in previous years as a partial control on current achievement. All tests contained some questions identical to those given to a pre-keypad class and several old tests were found that could be given almost entirely as photocopies of the original exams. Twenty years of old exams were available, excluding the last three years for which copies are placed on reserve for student study. Item analysis has been performed on both the present exams and on the control exams.

Interactive-lecture methods were continually modified based on this feedback from the students. Creating the kind of sessions that were instructionally most helpful (as judged by both students and the teacher) was extraordinarily time consuming. If testing the best use of the computer-assisted response system was to be the focus of the project, then the irreducible first priority was an effort to attain optimum use of the system. I feel satisfied that this was achieved to the best of my abilities within the limits imposed by time and money. However, this meant delaying the preparation of reports for publication or bringing together for comprehensive analysis the extensive evaluation data that was being accumulated. A graduate student specializing in educational evaluation was to be paid to analyze the massive body of data. A procedural plan was created; but, because of the disallowance of the no-cost extension, this activity has been deferred until an alternative can be devised.

Nonetheless, I will risk setting forth here some tentative conclusions which derive from the diverse appraisals used throughout the project for polishing my teaching methods. It remains to be seen if these conclusions are supported by a thorough analysis of the data. This is written as a frank and informal summary of my present thinking.

I judge the project a mixture of success and failure. In broad terms the success lay in the enhanced ability to communicate repeatedly with each class member during the lecture session. Because student responses often counted toward the course grade, attendance and attentiveness were exceptionally good. But, the goal that was most gratifying to reach was the ability to hold the class together in progressing through multistep problems. Our educational system has been criticized, most rightfully in my opinion, for not teaching realistic problem solving that involves identifying and solving intermediate problems to arrive at the desired answer. Addressing this deficiency was an ultimate ideal of the project. The best of interactive lecturing breaks the larger problem into small decision and calculation steps, each of which can be discussed with the class, and a solution path established. The students regroup at each way station before beginning the next leg of the journey. Multistep problems, however appropriate to a correct representation of science at the postsecondary level, tend to be avoided in conventional teaching because of the ease with which nonscience majors get lost along the way.

The failure, again in broad terms, lay in the inordinate amount of time that it takes to program such a multistep-problem sequence. After a subject is chosen as suitable, a storyboard must be created for the way that the steps will progress. Each step must be crafted with the care of an exam question to minimize ambiguities and to stimulate thought. But the bulk of the time is usually in formulating answer judgements and composing appropriate replies individualized to these answers (and constrained to three lines of 16 characters each) to send to the student screens. If some responses are to be scored for credit, the number of points assigned to the responses must be coded into the day program and included in the message to be sent back to the student. The presentation materials must then be prepared including overhead transparencies of the questions and of supplementary information. Because the computer program for the interactive lecture could be completely unusable because of a single programming or typographical error, it must be tested with a small set of keypads. At this point I frequently find improvements to make in the wording of the replies as well as in the logic of the judgements. The total time, including presentation, post-editing, record keeping, and a minimal evaluation can amount to several days work for a single class meeting when such an extensive interactive lecture is offered.

In spite of the time required, if the effort were rewarded with outstandingly improved student achievement, the project could be considered highly successful. We all know that it takes many, many hours to produce a single hour of tutorial computer-assisted instruction. But, my feeling is that student achievement was only marginally improved and even that may be hard to document with convincing evidence. In short, the results do not seem to justify the effort unless the interactive-lecture programs that were prepared are used repeatedly for a larger number of classes.

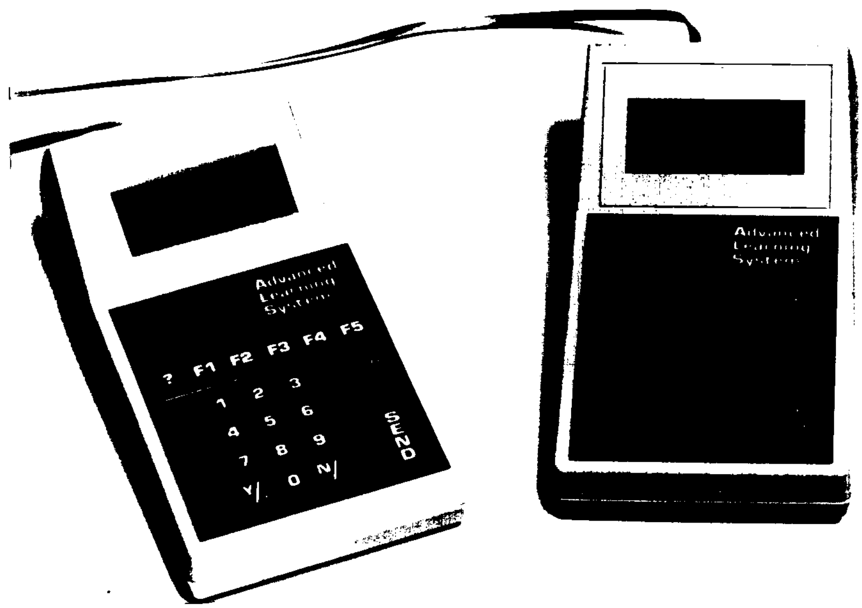
Most distressing was the constant reminder that some students could not be reached whatever I did. It may not be politically correct to verbalize this, but it is my reluctant conclusion that some attenders of our postsecondary institutions just cannot be motivated to an actual enjoyment of the intellectual activity demanded for higher education in science. In devising interactive lectures for multistep-problem solutions, my objective is to create intermediate questions which, although thought provoking, have fairly obvious, or, at least, straightforward answers. The idea is that most students are answering correctly these easy steps and are feeling good about their progress as we merrily progress to the shining solution at the edge of the forest. Of course, there is a limit to how simplistically one can break down a problem into trivial ministeps before one begins to cheat those students who are already motivated and capable of greater challenges. If interactive lecturing holds back these students, it should be buried quickly before it can do further damage. Elective introductory courses attract a clientele with an extreme range of backgrounds and abilities. My dilemma in finding the best compromise for teaching so diverse a group was that, no matter how trivial I made the ministeps, there were some students who would consistently miss them. After nearly 30 years of teaching, this should not come as a surprise to me, but a negative aspect of interactive lecturing is the very fact that class results are immediately displayed for the teacher's evaluation. To knowingly leave behind some students or to risk boring the majority with continual repetition of the elemental ideas is a frustration the interactive lecturer must be prepared to face -- and to contain, because it is not productive to display such frustration very often before the class.

Indeed, I came to suspect an element of counterproductivity in my efforts to reach all class members. That is, the more it was apparent that I considered it my mission to teach them astronomy, the less the responsibility they felt they needed to exercise toward that goal.

I was pleased to find that the students appreciated these sessions on multistep problems. It surprised me that even the best students considered them worthwhile, in spite of my trying to lead them into expressing negative criticism by pointing out (in the private interviews) that more material could be covered in class by traditional lecture methods. These student opinions were valued, but I would have preferred more concrete evidence that greater learning was being attained. It is difficult to assess the value of interactive lecturing in this area of multistep problems because I have no control group in which this objective was attempted by traditional methods.

In a wider context, the project also has value because of its obvious extendibility to distant learning where some, or all, class members are connected via phone line or fiber optics from remote sites. Also, with the increasing application of multimedia techniques and computer technology to lecture presentations, the methods of interactive feedback are likely to become a common component of such classes. This FIPSE project has accumulated data concerning the strengths and weaknesses of interactive lecturing.

G. Appendix



Photograph of keypads with personal messages as seen by students at the beginning of class.

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Table 1

Number of Fall Semester Astronomy Students
Responding to Evaluation Question in Two Years in Which an
Evaluation was Requested Just Before the First Exam and Also at the End of the Semester

"On a scale of 1 to 9, how helpful do you feel our system of interacting through the keypads is to your learning astronomy?"			"Was the 'Interactive Lecturing" response-pad system worthwhile?"		
Just before Exam 1 (Oct. 4-7). Keypad question.	1991	1992	Anonymous questionnaire at end of semester.	1991	1992
(9) = very, very helpful (8)	0 2	1 0	(8.5) = Strongly Positive	2	12
(7) = very helpful (6)	7 7	10 16	(6.5) = Positive	11	5
(5) = neither more nor less helpful than regular class methods	5	4	(5.0) = Neutral	7	4
(4) (3) = very unhelpful	3 2	4 4	(3.5) = Negative	5	5
(2) (1) = very, very unhelpful	0 1	0 1	(1.5) = Strongly Negative	3	4
(Average Value)	(5.59)	(5.60)	(Average Value)	(5.20)	(5.93)

By the end of the semester in 1992 we had won over a significant number of students to feeling strongly positive toward the keypad system; however, there continued to remain a group who were not happy with this change from methods with which they were familiar.

Table 2

Numbers of Fall Semester Students
Responding to Study-habits Questions

Compare the time that you spend studying for this course in relation to other courses.					
(Value)	1989 Oct.4	1990 Oct.19	1991 Oct.4	1992 Oct.7	1993 Dec.10
More for this (1.00)	10	15	8	8	11
Same as others (2.00)	27	12	17	20	6
Less for this (3.00)	10	6	2	13	3
(Average Value)=	(2.00)	(1.73)	(1.78)	(2.12)	(1.60)

If we did not use the response pads, I would probably spend					
(Value)	1989 Oct.4	1990 Oct.19	1991 Oct.4	1992 Oct.7	1993 Dec.10
More time (1.00)	-	1	5	6	1
About the same (2.00)	-	23	15	25	14
Less time (3.00)	-	9	7	10	5
(Average Value)=	-	(2.24)	(2.07)	(2.10)	(2.20)

Table 3

Numbers of Fall Semester Students
Responding to Attendance Questions

Compare your class attendance for this course to that for other, similar, courses						
Attend	(Value)	1989 Oct.4	1990 Oct.19	1991 Oct.4	1992 Oct.7	1993 Dec.10
this more often	(1.00)	14	9	7	11	8
about the same	(2.00)	33	22	20	28	11
this less often	(3.00)	2	0	0	1	0
(Average Value)=		(1.76)	(1.71)	(1.74)	(1.75)	(1.58)

If we did not use the response pads, I would probably attend						
	(Values)	1989 Oct.4	1990 Oct.19	1991 Oct.4	1992 Oct.7	1993 Dec.10
More often	(1.00)	-	0	0	1	1
About the same	(2.00)	-	25	20	25	14
Less often	(3.00)	-	6	7	12	5
(Average Value)=		-	(2.19)	(2.26)	(2.29)	(2.20)

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